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INFLUENCE OF ENVIRONMENT ON GROWTH AND REPRODUCTION OF CATTLE 1/

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Should our concept of environment on growth and reproduction of cattle be limited to the direct effects of temperature, humidity, precipitation, air movement, and sunlight? Or, should it also include the indirect effects of these weather conditions on growth and soil characteristics, and thus, interactions on kind and quality of forages and feeds available?

For many performance characteristics, direct effects have been rather thoroughly studied and we can describe them with considerable confidence. Under most climatic conditions in the United States for all cattle to a degree, but especially for beef cattle maintained under "natural" conditions, there is reason to believe that the indirect effects may be far more important as limiting factors for efficient production. Unfortunately, indirect effects are much less susceptible to critical study. Thus, we are left in the position of being able to review rather good information on the direct effects of some aspects of environment but to a considerable degree being limited to speculation regarding indirect effects. Therefore, in this discussion we will present a general review of environmental effects and project some ideas beyond areas which can be substantiated by rigid data.

DIRECT EFFECTS

Environmental Effects of Temperature and Related Climatic Factors on Cattle Growth

High Temperatures

Weight increase of European beef breeds is depressed at constant temperatures above approximately 75° F. The depression becomes

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progressively more severe until weight gain entirely ceases at temperatures of around 85° to 90° F., and prostration often occurs at around 105° F. Zebu-type cattle have a higher temperature tolerance than European breeds. Gains of Brahmans cease at about 90° F. (30). Reduction or cessation of weight increase at high temperatures is apparently due to (1) reduced voluntary feed intake and (2) increases in energy expended in heat dissipation, particularly through increased respiration rate. Reduced feed intake may well be a protective device to reduce metabolic heat production and thus reduce the heat load which may be dissipated. Temperature stress is followed by metabolic changes in the animal including modification of ruminal volatile fatty acid ratios, decline in thyroid activity, reduction of ascorbic acid, and CO_2 combining power of blood serum. These are probably partly effects of heat stress and partly attempts to modify metabolic processes to reduce heat production.

The foregoing are necessarily broad generalizations. Animal individuality is an important factor in determining when distress and/or reduced weight gains occur at high temperatures. It has been shown that acclimatization is a factor of some importance. In Missouri (30) work, animals maintained for extensive periods at 80° F. generally reacted more favorably to temperatures of up to 95° F. than did animals previously maintained at 50° F. In U.S.D.A. studies at Beltsville, Md., yearling heifers that were abruptly changed from ambient winter conditions to a heat chamber, maintained at a constant temperature of 90° F., went through a period of stress but continued to make small weight gains (25). Body temperatures initially went up but gradually decreased and were essentially at normal levels after about 12 weeks.

At high temperatures, age and condition of the animals affect their ability to gain weight. Observation by researchers doing heat chamber work indicates that older and fatter animals are more sensitive to high temperatures.

Type of ration is related to ability to gain at high temperatures. Low-fiber, high-energy rations are more conducive to gains than are high-roughage diets. The difference is apparently a result of the lower metabolic heat production on the low-fiber rations.

Missouri research (7) with dairy cattle indicates that the average daily temperature is a more important factor than extremes. For example, animals under diurnal regimes in which average temperature is 85° F. behave about like those under a constant 85° F. regime.

Other climatic factors affect reactions to high temperatures. High relative humidity is a factor in animal comfort at high temperatures

because it reduces evaporative heat loss--both surface and respiratory--in animals. The temperature-humidity index sometimes referred to as "discomfort index" is at least as important to cattle as to people.

Air movement or wind velocity is an important factor at high environmental temperatures because it is closely related to convective and evaporative heat loss. Tests in California (13) indicate that air movement of as little as 4 m.p.h. increased cattle daily gains by as much as 1 pound as compared to 1/2 m.p.h. Later tests showed no advantage of going above 3 to 5 m.p.h. Apparently a little wind is necessary, but a lot is no better!

Light is not known to have direct effects on growth or weight increase. However, Australian work (43) indicates that, at least in European breeds, shedding and hair growth are greatly influenced by light regimes. Hair coat has been shown in clipping experiments to be an important factor in heat tolerance and thus presumably in gain at high environmental temperatures. Cattle maintained on a constant daily light regime of 12 hours, 50 minutes (representative of tropical situations) resulted in all animals developing and maintaining a furry, heat-retaining type of coat of intermediate length. Light may be an important factor in the often observed failure of European breeds to "shed out" in subtropical areas.

Absorption of solar radiation, either direct or reflected from surroundings, is an important factor in aggravating high temperature stress. The heat load by absorption of solar radiation may range upward to 1,000 to 1,500 C. per hour or even more, which during a summer day may total as much as 10,000 C. or more--a figure as great and, in some cases, greater than metabolic heat production of the animal. A figure of 17,000 C. has been quoted as being absorbed by a dairy cow in a single summer day. Dissipation of this additional heat load puts added strain on the animal.

Grazing time is reduced during periods of high temperature and high solar radiation if shade is available. This may be due to several factors, the relative importance of which are not understood. It apparently is related to reduced feed intake and may contribute to reduced growth. Zebu-types are not affected as much as British breeds.

The fact is well established that high environmental temperatures are detrimental to cattle growth and reproduction and that certain related climatic factors tend to aggravate the effects of high temperatures. We are, therefore, interested in taking a look at where in the United States high temperatures are likely to be a problem in cattle production and what measures can be taken to alleviate temperature stress.

Figure 1 shows the average annual maximum temperatures for continental United States. You will note that extreme temperatures, which can be expected in the average year, are far above the comfort zone for cattle--either Zebu- or European-type--over the entire country, except in very limited areas and that in much of the Nation the figure is 100° F., or higher, that is, near the prostration point for European breeds.

Figures 2, 3, 4 show average July temperatures (July is the warmest month in most areas of the Nation). Here we see quite a different picture. The areas having average temperatures of over 80° F. for this month, are limited to nine Southeastern States and to small areas in the Southwest. The average daily range in temperature exceeds 15° F. in most of the Nation and exceeds 20° F. in all except some Southeastern coastal areas. Thus, in most areas cattle are below uncomfortable temperatures for part of the average day.

Figure 5 shows July average relative humidities. The Southeast again appears as the area where humidity, coupled with what we have already seen about temperature, can be a significant factor in cattle comfort and productivity.

The foregoing would seem to indicate that only in the Southeast and Southwest are temperatures high enough to constitute real deterrents to production. In other areas, temperatures for periods of short duration are above comfort zones and averages for the hotter months are borderline for the well-being of cattle. Available evidence, admittedly meager, coupled with production experience in these areas, indicates that growth is not seriously affected by high temperatures of short duration, if temperatures vary widely between day and night or if marked day-to-day fluctuations occur so that hot periods are of short duration. In either case, cattle apparently have an opportunity to recover from the effects of heat stress and to grow at a "normal" rate.

From a practical standpoint, experimental evidence indicates that anything which will reduce temperature stress through either (1) reducing heat loads, or (2) increasing heat elimination from the body will be effective in improving production (tables 1, 2, and 3). Some of these measures are:

a. Feed high-energy, low-roughage rations during periods of temperature stress.

   This is a highly practical approach for feedlot operations and for dairies but is usually not feasible for beef breeding herds.

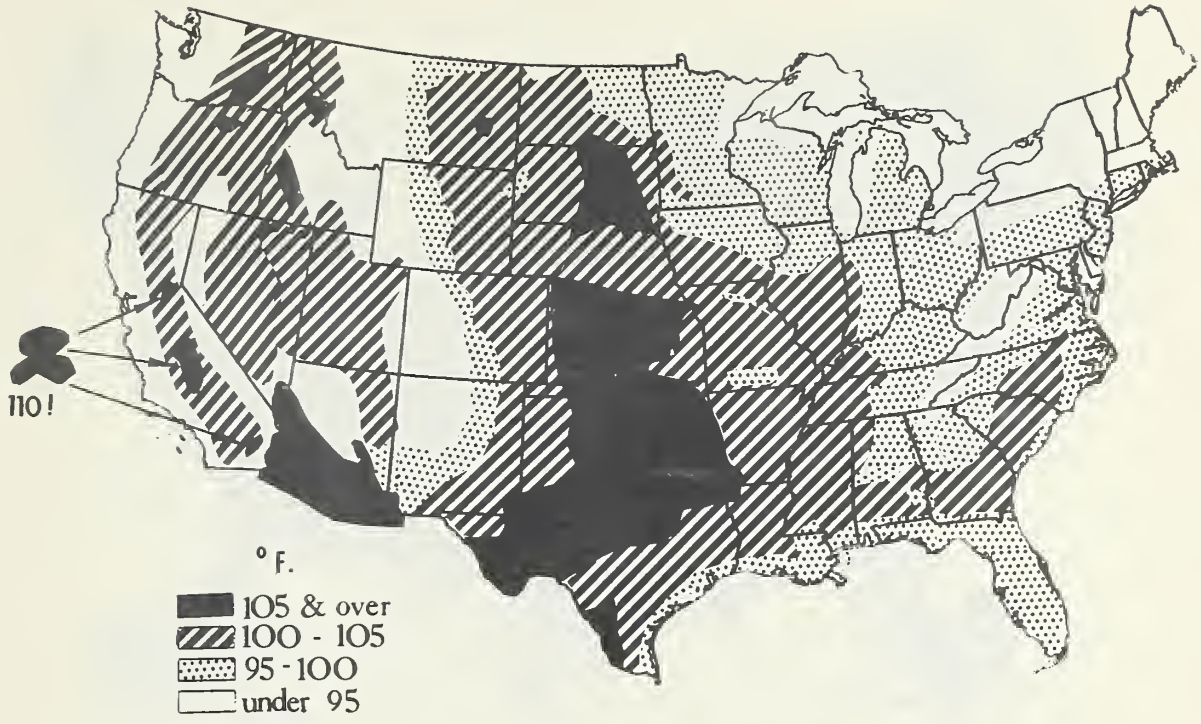

Figure 1.--Average annual maximum temperatures.

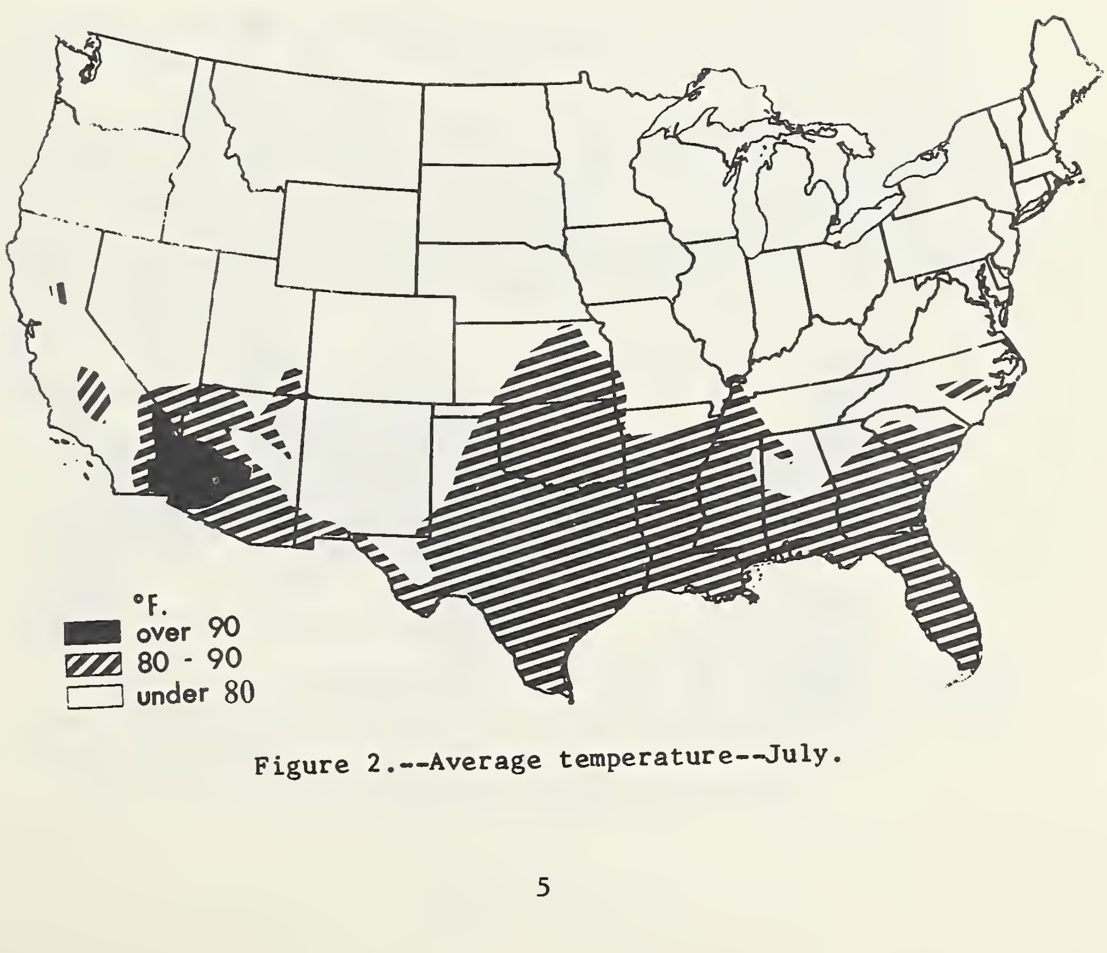

Figure 2.--Average temperature--July.

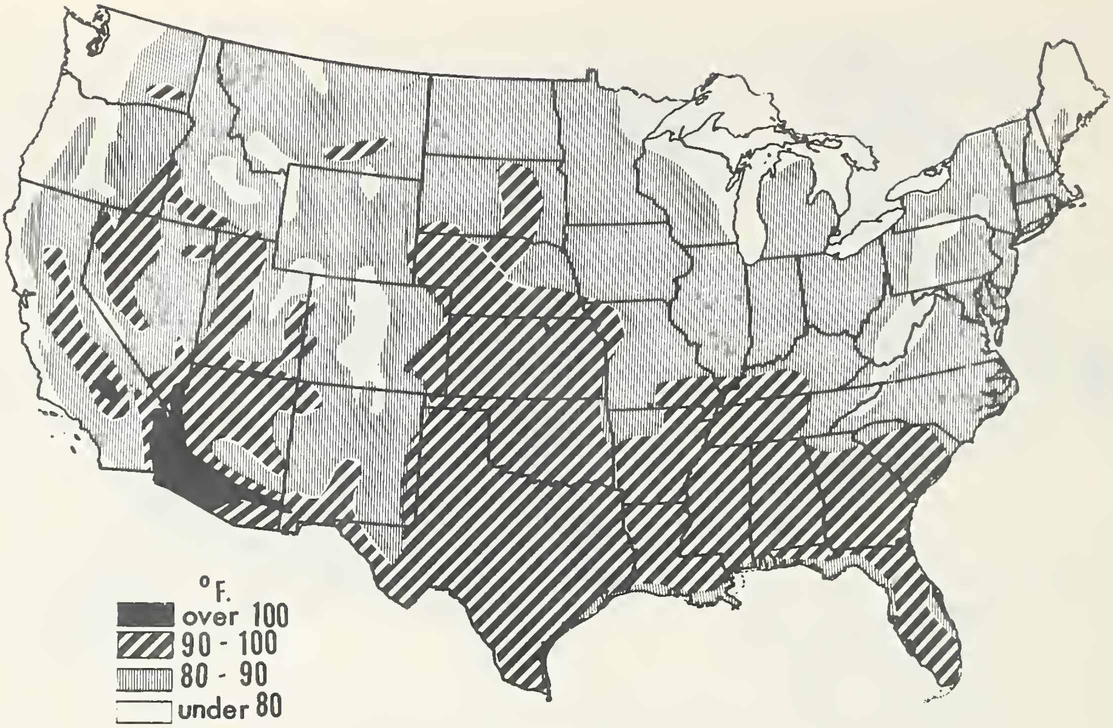

Figure 3.--Average maximum temperatures--July.

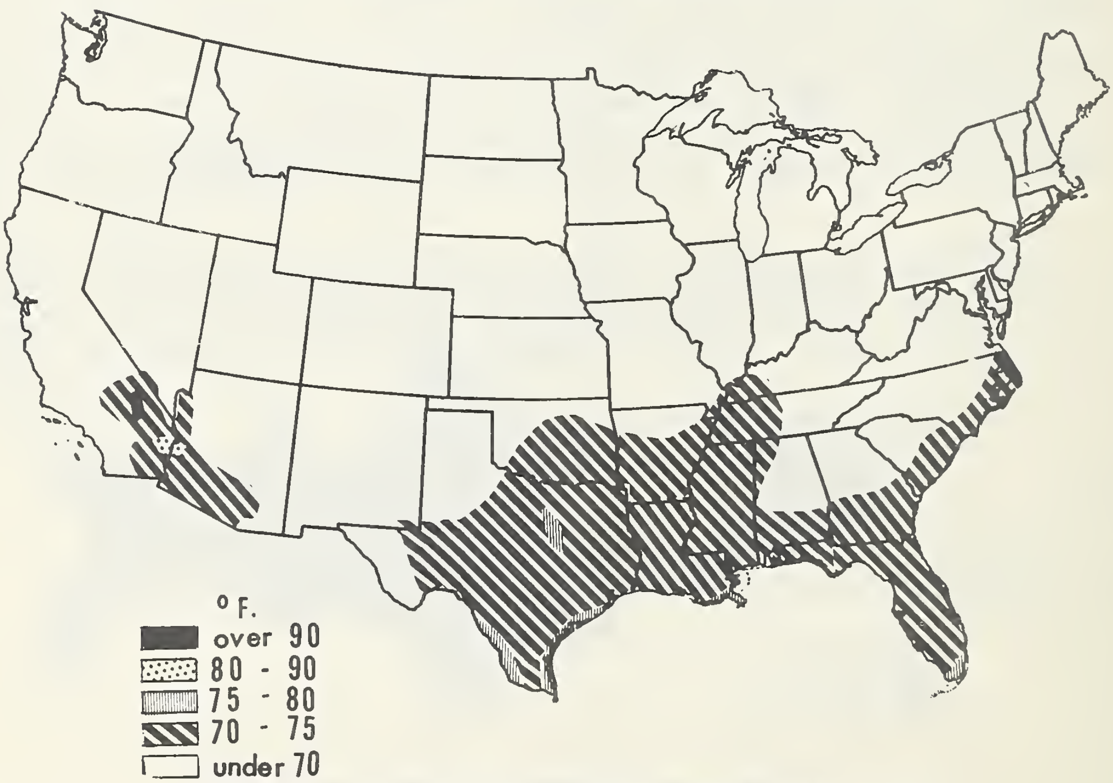

Figure 4.--Average minimum temperatures---July.

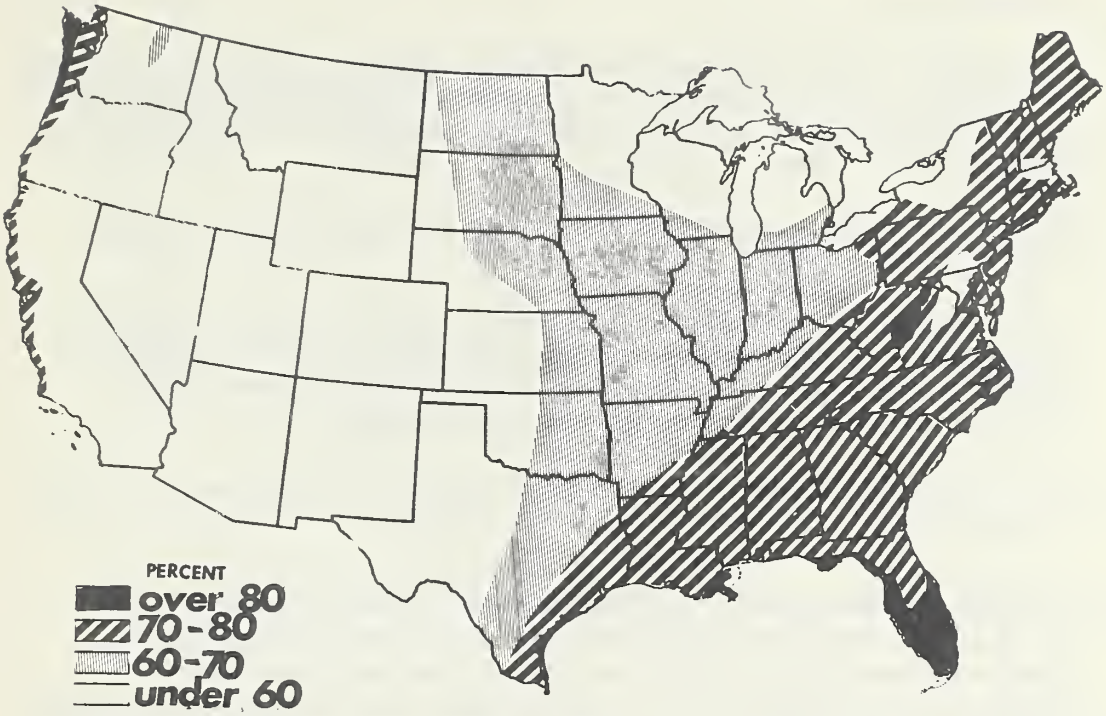

Figure 5.--Average relative humidity--July.

b. Provide shade for protection from solar radiation in areas where indicated.

This has been highly effective in Southwestern feedlots. Results in the Southeast have been variable. Quite possibly the variation in usefulness is related to cloud cover and haze, both of which absorb radiation, and to surroundings. Less solar radiation is reflected from green grass than from bare, light-colored soil and less from green trees than from board structures.

c. Insure adequate air movement.

Where natural wind velocity is very low, fans have been useful and economically feasible in Southwestern feedlots. Wire or cable corral fences allow more air movement and also reflect less solar radiation.

d. Provide cool drinking water.

This has been effective in Southwestern feedlots. Shading water tanks should be helpful in areas where artificial cooling is not practical.

e. Provide sprays.

Coarse sprays that wet the hair to the skin have been shown to be effective in reducing body temperature and increasing gains in dry Southwestern areas. It would presumably be less effective in more humid areas.

f. Adjust management and production systems to minimize conflicts with high temperatures.

Many things are possible here and will vary with type of operation. Possibilities include: Minimize feedlot activities during hotter months and reserve pastures with natural shade and/or cool running water for use in hot months.

g. Use breeds and types of cattle best adapted to the area and type of production.

We can summarize by saying that (1) there are no perfect breeds, (2) Zebu-type cattle are more heat tolerant than the European breeds, (3) light coat colors reflect more solar radiation than dark, and (4) some breeds have cancer-eye problems related to intensity of sunlight. Every producer must weigh the merits of available animal breeds and types in making decisions on kinds to produce.

TABLE 1.--Effect of shade on summer pasture gains

Cattle	Average daily gain (pounds)				Location	Reference
	No shade	Metal shade	Straw or hay shade	Natural shade		
Steers	1.04	---	---	1.49	Mississippi	(26)
Steers	1.31	1.37	1.35	---	Georgia	(23)
Steers	1.39	1.48	---	---	Georgia	(23)
Cows	-.05	.84	---	1.14	Louisiana	(24)
Calves	1.18	1.78	---	1.75	Louisiana	(24)
Cows	1/ 144	1/ 182	---	---	Oklahoma	(37)
Calves	2/ 432	2/ 414	---	---	Oklahoma	(37)

1/ Total summer gain.
2/ Weaning weight.

TABLE 2.--Effects of shade on summer fattening gains

Average daily gains (pounds) No shade	Average daily gains (pounds) Shade	Location	Reference
1.74 1/	2.21 1/	California	(13)
1.46 2/	1.92 2/	Arizona	(28)
1.99	2.12	Kansas	(6)
2.16 3/	2.21 3/	Georgia	(23)
2.00 4/	2.14 4/	Georgia	(23)

1/ Averages of lots with and without fans.
2/ Averages of steers and heifers with and without diethylstilbestrol. Aluminum shade.
3/ Drylot.
4/ Pasture.

TABLE 3.--Effects of season and ration on steer gains

Ration	Average daily gains (pounds)		
	Winter	Summer 1/	Decrease summer
			Percent
Alfalfa hay, actual	1.74	0.97	44
Alfalfa hay, expected	1.50	1.50	--
Alfalfa hay plus grain, actual	2.31	1.58	32
Alfalfa hay plus grain, expected	2.20	1.70	--

1/ Water not cooled--from California Bulletin 761 (20).

Low Temperatures

Low temperatures are less of a problem in cattle production than high temperatures. In fact, cattle have sometimes been spoken of as being an Arctic species. There can be no doubt of the basic truth of this generalization, but it has perhaps served as an unjustified basis for failing to make critical studies on effects of low temperatures (figures 6 and 7). At least very few such studies have been made.

Cold has deleterious effects on the efficiency of production whenever heat loss exceeds the metabolic heat production resulting from a feeding regime normal for the type of production being aimed for. The danger of death of newborn calves in cold environments is a most extreme example.

Blaxter and Wainman in Scotland (2) determined the critical temperatures of two 2-1/2 year old Angus cross steers weighing about 1,100 pounds to be approximately as follows:

Feeding Level	Critical Temperature °C	Critical Temperature °F
Maintenance	6.2	43.2
Submaintenance	11.6	52.9
Fasting	18.1	64.6
Fed dry ration to gain 2 lb. daily 1/	-7	19.4
Fed roots, straw, and cake to gain 1 pound daily 1/	3.3	37.9

1/ Calculated figures.

Below these temperatures an animal will be using energy from feed to maintain body temperature rather than for productive purposes. Blaxter and Wainman (2) estimated that for the steer fed to gain 1 pound daily an addition of 3/4 pound of oats to the daily ration would be necessary at 0° C. to maintain the rate of gain.

The critical temperatures determined by Blaxter and Wainman (2) are in good general agreement with results from dairy cattle. General indications are that growth and/or milk production of well-fed animals are not reduced at temperatures well below freezing but that feed consumption tends to increase. Milk production is somewhat reduced at constant temperatures of 5° to 15° F.

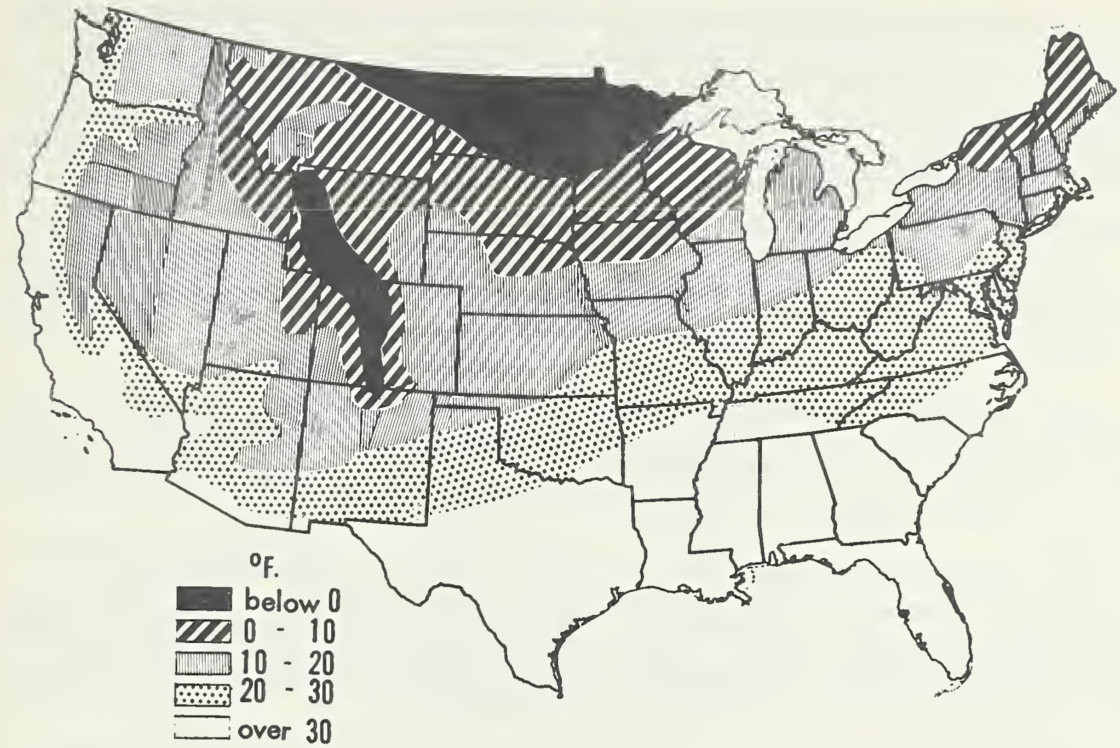

Figure 6.--Average minimum temperature--January.

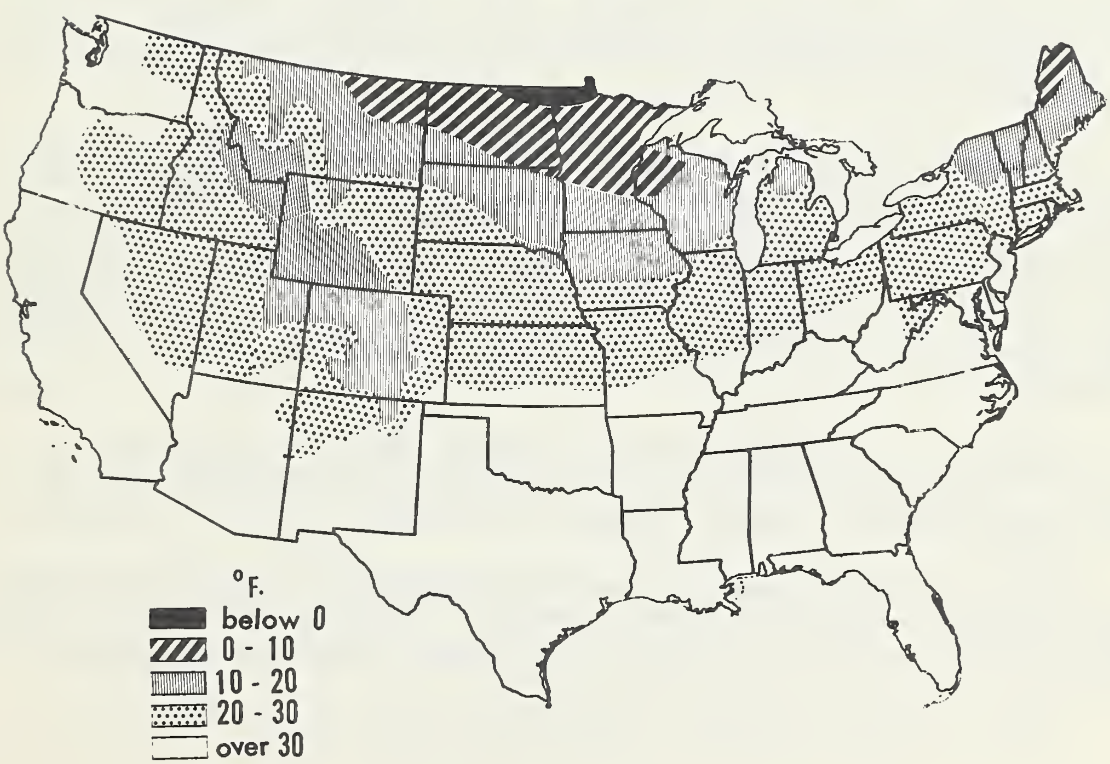

Figure 7.--Average temperature--January.

To our knowledge no research has been done on the effects of age and condition on the critical temperatures of cattle at various levels of nutrition. The general expectation, however, is that older and fatter animals would be better able to withstand low temperatures. The character of hair coat undoubtedly also has an important effect, but this apparently has not been studied critically.

Little is known about the effects of duration of exposure of cattle to low temperatures, cold rains, and driving blizzards. Driving blizzards must increase convective heat loss and thus raise the critical temperature of cattle.

Some questions apparently unanswered at present are: Are the effects of an average low temperature, with normal diurnal variation, the same as effects of a constant low temperature? Are there carryover effects of a few hours' exposure to cold rains or blizzards?

Some experiments have been conducted in which different types of shelter have been compared in winter for cattle of various classes. For many of these studies, very little detailed information was given on air temperatures, precipitation, wind velocity, and depth and temperature of manure pack if manure was allowed to accumulate.

First, it is apparent from practical observation, as well as from the work of Cowan and associates (9, 16, and 18) of Connecticut and from the performance of the "No Protection" lots in several experiments, that beef cattle in a reasonably good state of nutrition can maintain health and thrift with no protection under all but the most severe climatic conditions.

The data in available experiments indicate, however, that fattening steers in all but one comparison gained slightly faster if they had some protection even in States as far south as Alabama (table 4). Further, in all cases where this information was reported, there was an increase in feed required per unit gain for lots with no protection. The few experiments of this type conducted in semiarid areas of the West have shown only small differences, and no studies are known to have been made in the warmer Southwest.

Available data indicate that for full-fed cattle an open shed is adequate in all climates where such studies have been made and that in most cases windbreaks were as effective as sheds or barns. (Table 5.)

Data are much more scanty on shelter requirements for beef animals being wintered at lower nutritional levels. Available data on both stockers and brood cows indicate lower gains (or greater losses in body weight) for

TABLE 4.--Effect of shelter on winter gains of fattening beef cattle

Age	Average daily gain (pounds) No protection	Open shed	Barn	Location	Reference
2 year	---	2.10	2.02	Pennsylvania	(8, 21, 22)
2 year	2.05	1.99	1.78	Missouri	(39)
2 year	1.48	1.56	---	Oregon	(29)
Calves	1.90	1.87	---	Oregon	(29)
2 year	1.65	1.73	---	Idaho	(19)
Yearlings	2.22	2.27	---	Idaho	(19)
Steers	1.67	1.71	---	Alabama	(14)
Steers	1.47	1.55	---	Alabama	(11)

TABLE 5.--Effect of shelter on winter gains of fattening beef cattle

Age	Average daily gain (pounds) No protection	Wind-break	Open shed	Barn	Location	Reference
Yearlings	1.92	2.40	2.26	--	Canada	(40)
Yearlings	--	1.72	1.84	--	Canada	(41)
Calves	--	1.92	2.01	--	Nebraska	1/
Calves	2.16	--	2.23	--	Kansas	(33)
Yearlings	--	2.48	--	2.96	Iowa	(32)
Calves	2.22	--	2.33	--	Connecticut	(17)

1/ Private communication from Donald C. Clanton, June 24, 1964.

cattle of these classes, if they have no shelter as compared to barns or open sheds (table 6). Interestingly enough, the only experiments we've been able to find on these classes of cattle are in the South. It would appear to be a field of work in which more research is needed.

TABLE 6.--Shelter for wintering beef cattle

Cattle	Winter gain or loss (pounds)				Location	Reference
	No protection	Trees or brush	Open shed	Barn		
Cows	-26	--	--	+22	Mississippi	(35)
Cows	-123	--	-46	--	Alabama	(15)
Cows	--	-18	--	+9	Tennessee	(36)
Yearlings	+71	--	--	+108	Mississippi	(35)
Calves	+52	--	--	+64	Mississippi	(35)
Yearlings	--	+55	--	+82	Tennessee	(12)

Basically, in most areas of the Nation where temperatures are below critical levels for a given class of cattle, the question of winter shelter is a simple economic one; that is, will production costs be greater if no shelter is provided and extra feed is required or if money is expended on shelter with a resultant saving in feed? These questions have apparently been very inadequately studied with both beef and dairy cattle. In South Dakota studies (1), dairy heifers in a well-insulated barn gained 1.03 pound per day versus only 0.63 pound per day in a non-insulated cold barn. Feed required per pound of gain was more than doubled in the cold barn.

In addition to the type of problem discussed above for which adequate information could be developed if we had more well-controlled experimentation, the cattleman in making shelter plans always has to take into account the possibility of occasional catastrophic losses due to unusually severe weather. Losses of western cattlemen in the winter of 1886-87 are part of the lore of the industry. The winter of 1947-48 could well have been equally disastrous had it not been for the Air Force's "hay lift" and other emergency activities. Losses are not limited to the West. The

senior author, while driving most of the length of Florida during the second week of February 1951, saw dead cattle by the thousands. This resulted from a sudden cold rain. While many of the deaths were of poorly fed animals, reasonably well-fed ones also died. On the edge of the Everglades, losses were about 5 percent in one well-fed herd of over 4,000 head. Minimum temperature had not gone below freezing. We are far from having an understanding of why or how shock can be severe enough to kill under such circumstances.

Pending the development of more precise information, it would seem that cattlemen should proceed as follows:

1. Spend money for shelter only as experience in a given area indicates is necessary.
2. Make full use of trees, brush, and irregularities of terrain as shelter.
3. Feed more heavily on roughage than normal during periods of more severe weather stress.

Effects of Environmental Variables on Cattle Reproduction

Successful reproduction in cattle as in all mammalian species depends upon the successful completion and synchronization of a large number of steps or processes ranging from germ-cell production through mating, fertilization, and gestation to the delivery of live young. Each step can be successfully completed only if the physiological background processes have been successful. Thus, it is not unexpected that reproduction is highly subject to environmental influences.

Reproduction rate in cattle varies with the area. Figure 8 (38) represents estimates, by States, of calves dropped during the year as a percentage of females 2 years old and older in the national inventory on January 1. Because many females under 2 years of age on January 1 do calve during the year, the figures are an overestimate of calf crop but should be unbiased for comparing different section of the country.

Innumerable variables could potentially affect calf crop from a given area, but it is perhaps more than coincidental that the areas with lowest rates are nearly the same as those with highest summer temperatures.

In most areas having high summer temperatures the summer months have the lowest reproductive efficiency. In these areas it has usually been found that semen quality is lowest in the summer. As with other species, it has been found in laboratory studies that semen quality deteriorates under continuous high temperatures; 85° F. or higher seems to be critical for dairy bulls.

Prior to the advent of artificial insemination with frozen semen, it had not been possible to ascertain whether lowered summer fertility was solely attributable to lowered semen quality. Recent Arizona work (34)

has demonstrated, however, that apparently both lowered fertilization rate and increased prenatal embryonic mortality occur during months of high temperatures even though stored frozen semen, collected prior to the breeding season, was used. This indicates direct effects of high temperature on the cow.

Laboratory studies of effects of high temperatures on female reproductive function have not been extensive. Missouri workers (10) found that initiation of ovarian activity in heifers was delayed in Shorthorns and Brahmans reared at 80° F. as compared to those reared at 50° F., or in an open shed, but that Santa Gertrudis animals were not greatly affected.

In USDA studies (3) at Beltsville, beef and dual-purpose post-puberal heifers were placed in a control chamber at 90° F., and 65 percent relative humidity during the winter and kept there for a period of 29 weeks. Five of the six heifers became anestrous after a few weeks of exposure but later reestablished estrual cycles. While in the chamber, five of the six became pregnant and maintained normal pregnancies to the end of exposure (average 66 days).

All of a group of heifers put in the chamber at 90° F. and 60 percent relative humidity during the summer months, while presumably conditioned to high temperatures, maintained regular estrual cycles. All except one of the same group of heifers ceased to cycle after the chamber temperature was raised to 100° F. and 60 percent relative humidity (4).

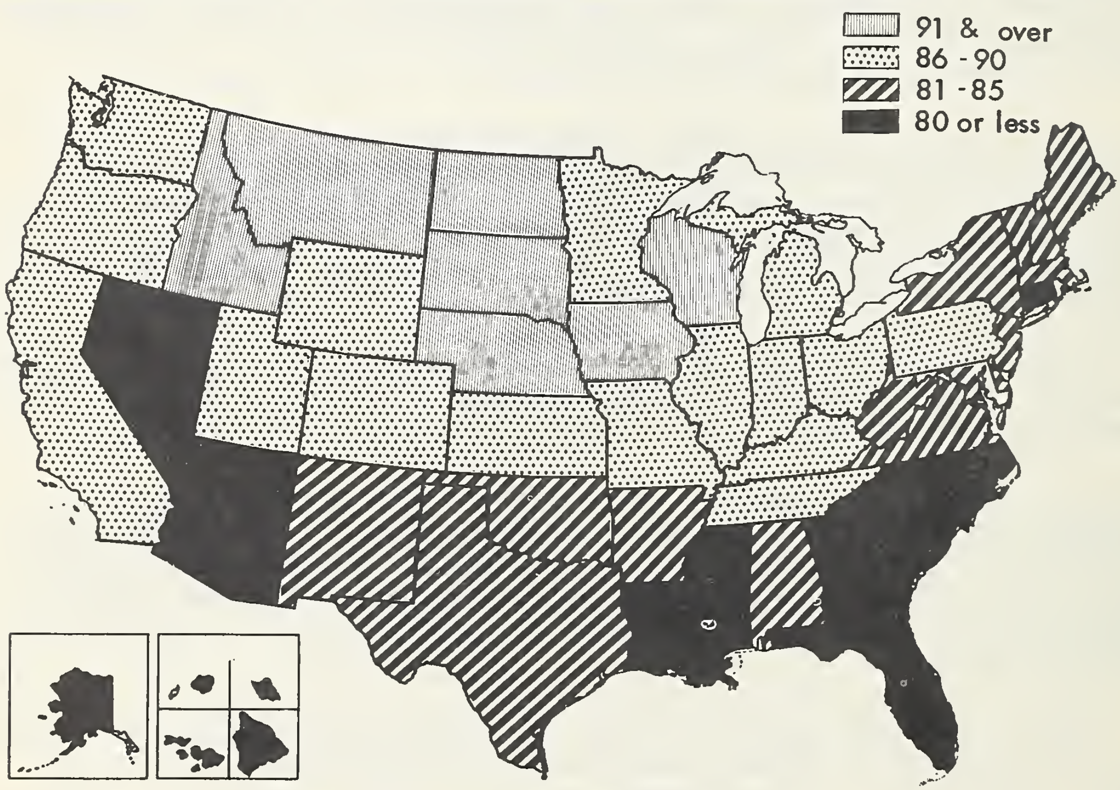

Figure 8.--Calves per 100 cows.

These experiments indicate that severe temperature stress will interrupt estrual cycles but also suggest that the conditions necessary to accomplish this seldom would be encountered under natural conditions.

Bonsma (5) in South Africa has observed drastically reduced birth weights of calves born to British cows after summer pregnancies. No effect was observed in Africander cows.

In areas of the North American continent where high summer temperatures are not a consistent climatic feature, studies have shown that fertility tends to be lowest in the winter months. This can be associated with light, since days are shorter in winter. This seems a reasonable hypothesis in view of the proven effects of light on reproduction in other species but has apparently not been proven experimentally. Louisiana workers (31) have demonstrated the effectiveness of lengthened days in improving semen quality in dairy bulls during the summer and fall.

Most cattle are polyestrous, that is, they have regular estrual cycles the year round, but Missouri studies and observations from the South suggest that, at least under certain conditions, Zebu-type cattle undergo extended anestrual periods during the winter months. Observations indicate that in some cases post-puberal females of English breeds may undergo periods of anestrous after periods of severe winter weather--particularly if on rather limited rations.

INDIRECT CLIMATIC EFFECTS

For beef cattle, reared under typical management regimes with maximum use of pasture forage, and to a lesser extent for dairy cattle, the indirect effects of climate on performance are profoundly important. Some of these, such as climatic conditions limiting the length of the grazing season, are so obvious as to require no discussion.

The indirect effects of climate on cattle performance through effects on soils and types and varieties of forages and other crops which can be grown are less obvious. In many cases they are not well understood, but are probably of importance.

Summer forages in the warm, humid areas of the Nation tend to be low in nutritive value for one or more of the following reasons (27).

1. High water content.
2. High fiber content per unit dry matter.
3. Low protein content per unit dry matter.
4. Low content of the more digestible carbohydrates.
5. No adapted legumes to grow in grass mixtures.

In these areas, because high rainfall leaches out nutrients during dormant seasons, forage does not cure on the ground as it does in the semiarid West. Thus inadequate nutritional level rather than direct climatic effects, may wholly or partly cause low cattle performance in some areas.

This situation can be illustrated by the following data. The first is from work by Wiltbank et al. (42) in which weanling heifers were fed at Jeanerette, La., and Beltsville, Md., on a factorial type experiment with three levels of total feed (energy) and three levels of protein (table 7). At the medium and high levels of energy, reproductive performance seemed to be quite similar at the two locations in spite of differences in cattle types.

The second is a study at Jeanerette, La., (table 8) of pregnant yearling heifers maintained under four feeding regimes--two designed to meet probable nutrient requirements and two to represent what might be expected from pasture in the area. Post-partum reproductive performance was quite satisfactory in heifers on adequate nutritional regimes whether on pasture or in drylot but was unsatisfactory for those on pasture or its equivalent.

Material such as the above, together with many observations of good beef cattle performance, including summer performance of feedlot steers, in much of the South when nutritional levels are adequate, emphasizes the importance of adequate nutritional levels.

There is no doubt of direct adverse climatic effects for short periods of time in much of the South. However, from the standpoint of year-round performance, nutrient levels (i.e., indirect climatic effects) are likely of much greater importance than direct debilitating effects of high temperatures and humidity.

In no sense does this mean that producers should not take all economically feasible measures to minimize reduced production that result from direct climatic effects.

It does mean, however, that we shouldn't overlook other reasons for subnormal production.

TABLE 7.--Reproductive performance at two locations 1/

Item	High energy level		Medium energy level	
	Md.	La.	Md.	La.
Days to puberty	117	114	157	127
Wt. at puberty, pounds	504	560	490	500
Percent conception, first pregnancy	93	100	100	93
Post-partum interval, days	70	46	67	72
Percent conception, second pregnancy	100	100	100	100

1/ From USDA Technical Bulletin 1314 (42).

TABLE 8.--Reproductive performance 1/ 2-year-old lactating cows, Jeanerette, La.

Item	Fed to NRC 2/ Standards		Pasture or equivalent	
	Drylot	Pasture	Drylot	Pasture
Interval, calving to first heat, days	113	100	141	122
Not showing heat, percent	--	--	8	15
Pregnant, 90-day breeding season, percent	85	82	50	54

1/ W. L. Reynolds and others unpublished.
2/ National Research Council of National Academy of Sciences.

References

(1) Battle, E.
1951. Does a main barn pay? South Dakota Report, pp. 18-21.

(2) Blaxter, K. L., and Wainman, F. W.
1964. The effect of increased air movement on the heat production and emission of steers. J. Agr. Sci. 62: 207.

(3) Bond, J., McDowell, R. E., Curry, W. A., and Warwick, E. J.
1960. Reproductive performance of milking shorthorn heifers as affected by constant high environmental temperature. J. Anim. Sci. 19: 1317. (Abs.)

(4) Bond, J., Weldy, J. R., McDowell, R. E., and Warwick, E. J.
1961. Responses of summer-conditioned heifers to 90° F. J. Anim. Sci. 20: 966. (Abs.)

(5) Bonsma, J. C.
1955. Degeneration of the British beef breeds in the tropics and subtropics. In "Breeding Beef Cattle for Unfavorable Environments." Univ. of Texas Press.

(6) Boren, F. W., Smith, E. F., Hodges, T. O., Larson, G. H., and Cox, R.
1961. Shade for feedlot cattle. Kans. Agr. Expt. Sta. Tech. Bul. 120.

(7) Brody, S., Ragsdale, A. C., Yeck, R. G., and Worstell, D. M.
1955. Environmental Physiology and Shelter Engineering. XXXIII. Mo. Agr. Expt. Sta. Res. Bul. 578.

(8) Cochel, W. A., and Doty, S. W.
1910. Methods of fattening steers. Pa. Agr. Expt. Sta. Bul. 102.

(9) Cowan, W. A., Grant, D. A., and Hale, N. S.
1964. Comments on wintering dry beef brood cows (Angus and Hereford) at University of Connecticut. Univ. of Conn., Animal Indus. Dept. Mimeo.

(10) Dale, H. E., Ragsdale, A. C., and Cheng, C. S.
1959. Environmental physiology and shelter engineering. LI. Mo. Agr. Expt. Sta. Res. Bul. 704.

(11) Duggar, J. F., and Ward, W. F.
1908. Experiments in beef production in Alabama. USDA-BAI Bul. 103.

(12) Duncan, H. R., Hobbs, C. S., and Felts, J. H.
1956. The influence of different methods of wintering and nitrogen and water applications on Bluegrass pastures during the summer on the production of slaughter yearlings. Univ. of Tenn. AH-VS Mimeo. 102.

(13) Garrett, W. N., Bond, T. E., and Kelly, C. F.
1960. Effect of air velocity on gains and physiological adjustments of Hereford steers in a high temperature environment. J. Anim. Sci. 19: 60-66.

(14) Gray, D. T., and Ward, W. F.
1911. Steer feeding in Alabama. Ala. Agr. Expt. Sta. Bul. 163.

(15) Grimes, J. C.
1942. Value of shelter for wintering beef breeding cows. Ala. Polytech. Inst. 53rd Ann. Rpt., Agr. Expt. Sta.

(16) Hale, N. S., Cowan, W. A., and Grant, D. A.
1963. Outwintering observations on yearling replacement beef heifers. Univ. of Conn., Dept. Animal Indus., Mimeo.

(17) Hale, N. S., Cowan, W. A., and Grant, D. A.
1964. Comparison of shelter versus no shelter in steer calf corn silage feeding programs. Univ. of Conn., Dept. Animal Indus., Mimeo.

(18) Hale, N. S., Cowan, W. A., and Grant, D. A.
1964. Outwintering observations on yearling replacement beef heifers. Univ. of Conn., Dept. Animal Indus., Mimeo.

(19) Hickman, C. W., Rinehart, E. F., and Johnson, R. F.
1934. Fattening Idaho range cattle. Idaho Agr. Expt. Sta. Bul. 209.

(20) Ittner, N. R., Bond, T. E., and Kelly, C. F.
1958. Methods of increasing beef production in hot climates. Calif. Agr. Expt. Sta. Bul. 761.

(21) Mairs, T. I., and Tomhane, W. H.
1908. Steer feeding experiments 1907-08. Pa. Agr. Expt. Sta. Bul. 88.

(22) Mairs, T. I.
1906. Methods of steer feeding. Pa. Agr. Expt. Sta. Rpt., pp. 145-50.

(23) McCormick, W. C., Givens, R. L., and Southwell, B. L.
1963. Effects of shade on rate of growth and fattening of beef steers. Ga. Agr. Expt. Sta. Tech. Bul. NS. 27.

(24) McDaniel, A. H., and Roark, C. B.
1956. Performance and grazing habits of Hereford and Aberdeen-Angus cows and calves on improved pastures as related to types of shade. J. Anim. Sci. 15: 59-63.

(25) McDowell, R. E., Bond, J., McDaniel, B. T., and Warwick, E. J.
1960. Influence of 90° F. environmental temperature on certain physiological responses of Milking Shorthorn heifers. J. Anim. Sci. 19: 1329. (Abs.)

(26) Mississippi Agricultural Experiment Station.
1954. Report for year ending June 30, 1953. Report on shade for steers at Black Belt Station, pp. 58-59.

(27) Morrison, F. B.
1948. Feeds and Feeding. 21st Ed. Morrison Pub. Co. Ithaca, N.Y. 1098 pp.

(28) Nelms, G., and Roubicek, C. B.
1958. The effect of shade, type of shade, and stilbestrol on the performance of summer-fed Hereford steers and heifers in southwest Arizona. Proc. Western Sect. Amer. Soc. Animal Production 9: 25.

(29) Potter, E. L., and Withycombe, R.
1921. Shelter and warm water for fattening steers. Oreg. Agr. Expt. Sta. Bul. 183.

(30) Ragsdale, A. C., Cheng, C. S., and Johnson, H. D.
1957. Environmental physiology and shelter engineering. XLII. Mo. Agr. Expt. Sta. Res. Bul. 642.

(31) Roussel, J. D., Patrick, T. E., Kellgren, H. C., and Guidry, A. J.
1964. Influence of incandescent light on reproductive and physiological responses of bovine bulls. J. Dairy Sci. 47: 175.

(32) Self, H. L.
1962. Shelter and paving management studies with feedlot steers. Iowa State Univ. A. S. Leaflet R44.

(33) Smith, E. F., Richardson, D., Deyoe, C. W., Boren, F. W., and Curtis, R. G.
1964. Cane molasses in rations of growing beef calves. The value of winter shelter for feedlot calves. 1963-64. Kans. Agr. Expt. Sta. Bul. 473.

(34) Stott, G. H.
1961. Female and breed associated with seasonal fertility variation in dairy cattle. J. Dairy Sci. 44: 1698.

(35) Templeton, G. S.
1929. Beef cattle production in Mississippi. Miss. Agr. Expt. Sta. Bul. 268.

(36) Tennessee Livestock Producers' Days Report.
1961. Tenn. Agr. Expt. Sta.

(37) Totusek, R., Nelson, A. B., Gallup, W. D., and Darlow, A. E.
1953. The value of trace minerals, phosphorus in drinking water, parasite treatment and shade for beef cows in southeastern Oklahoma. Okla. Agr. Expt. Sta. Misc. Pub. MP-31.

(38) United States Department of Agriculture.
1964. Agricultural Statistics. 632 pp., Washington, D. C.

(39) Waters, H. J.
1907. Fattening cattle for the market. Mo. Agr. Expt. Sta. Bul. 76.

(40) Williams, C. M.
1958. Experiments on bedding and shelter for beef cattle. Univ. of Saskatchewan, 3rd Annual Stockman's Day, Dept. of Anim. Sci., pp. 36-38.

(41) Williams, C. M.
1959. A comparison of Charbray-sired and Hereford-sired steers. Univ. of Saskatchewan, 4th Annual Stockman's Day, Dept. of Anim. Sci., pp. 16-18.

(42) Wiltbank, J. N., Bond, J., and Warwick, E. J., and others.
1965. Influence of total feed and protein intake on reproductive performance in the beef female through second calving. U. S. Dept. Agr. Tech. Bul. 1314, 45 pp.

(43) Yeates, N. T. M.
1955. Photoperiodicity in cattle. Aust. J. Agr. Res. 6: 891.